14 December 2001

Proposal:

ARB RFP Task 6.4:
Analysis of Data Generated by Clean Airship I During the Wintertime CRPAQS Field Measurement Program Intensive Operating Periods

Submitted To:

Mr. Don McNerny, Program Manager
California Regional PM10/PM2.5 Air Quality Study
California Air Resources Board
Planning and Technical Support Division
1001 "I" Street
Sacramento, CA 95814

Submitted By:

Thomas J. Rappolt
Tracer Environmental Sciences & Technologies, Inc.
970 Los Vallecitos Blvd., Suite 100
San Marcos, CA 92069

Statement of Offer

The statements contained in this proposal and the quoted rates along with the total projected budget will remain in effect for a period of not more than 120 calendar days from the date of 14 December 2001.

Additionally, the undersigned has reviewed the terms and conditions of the sample contract contained in the October 22, 2001 RFP and agrees to comply if awarded a contract.

It is Tracer ES&T, Inc. understanding that no DVBE subcontracting is necessary with this program. Should that become a requirement, due to disclosure from ARB that this program is supported by Federal funds, Tracer ES&T, Inc. is prepared to allocate the required percentage of total contract funds to a certified DVBE. Tracer ES&T has demonstrated a clear history of compliance to this statute on other ARB contracts it has conducted.

Respectfully Submitted,

Thomas J. Rappolt
President of Tracer ES&T, Inc.

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1.0 Overview and Background

This proposal is in direct response to the October 22, 2001 ARB Request for Proposal (RFP) entitled "California Regional PM10/PM2.5 (CRPQAS) Initial Data Analysis of CRPAQS Field Programs. Specifically, the subtasks identified in this proposal are focused on addressing Task 6.4 of the RFP which presents the following questions:

- What are plume dispersion and diffusion characteristics under low wind speed, low visibility conditions in the SJV?

- How does plume dispersion and diffusion vary in the SJV with height and time of day? (Program data may be limited to address this issue completely)

- When and where do elevated plumes remain within the valleywide layer and/or mix to the surface?

Analysis of the Clean Airship 1 database will provide insight to the answers of these questions in addition to others as they are revealed in the program Work-Plan. An initial work plan is provided with this proposal, but will be refined as an outcome of the first subtask.

1.1 Development Program

In 1998 the U.S. Department of Energy (DOE) embarked upon a feasibility study to research possible ways to sample air quality plumes from fossil energy plumes, especially in their early stages of transport from the source, to better understand the physical dynamics that contribute to plume buoyancy and secondary aerosol deposition. DOE, along with industry partnerships, including the Western States Petroleum Association (WSPA) and Tracer Environmental Sciences & Technologies, Inc. (Tracer ES&T), explored concepts of a sampling platform that could easily and safely access plume dynamics to support more accurate modeling and the assessment of fossil energy impacts to ambient air quality. The requirement was to conduct plume monitoring during low and near zero visibility conditions (i.e. fog) which cannot be accomplished using manned flight vehicles or fast moving fixed winged vehicles. The dynamics of the problem require a flexible, slow flying, highly maneuverable sampling platform, from which detailed plume measurements can be made. Hence a remotely piloted airship, under an instrument guidance and control system, offered the best approach. Such a platform, carrying miniaturized sampling/monitoring payloads, is useful in providing detailed data concerning the vertical structure of near-term plumes as well as ambient chemistry.

After more than a year of experimentation and engineering, a suitable platform was developed using a 30ft by 8ft helium filled mini-blimp combined a state-of-the-art GPS navigational system and communications package. The mini-airship (hence labeled Clean Airship 1) prototype is completely automated in that it is piloted remotely and continuously transmits realtime measurement data

(including position in three dimensions) to a ground control work station. The Clean Airship 1 approach to airborne measurement of plumes is presented in Figure 1.

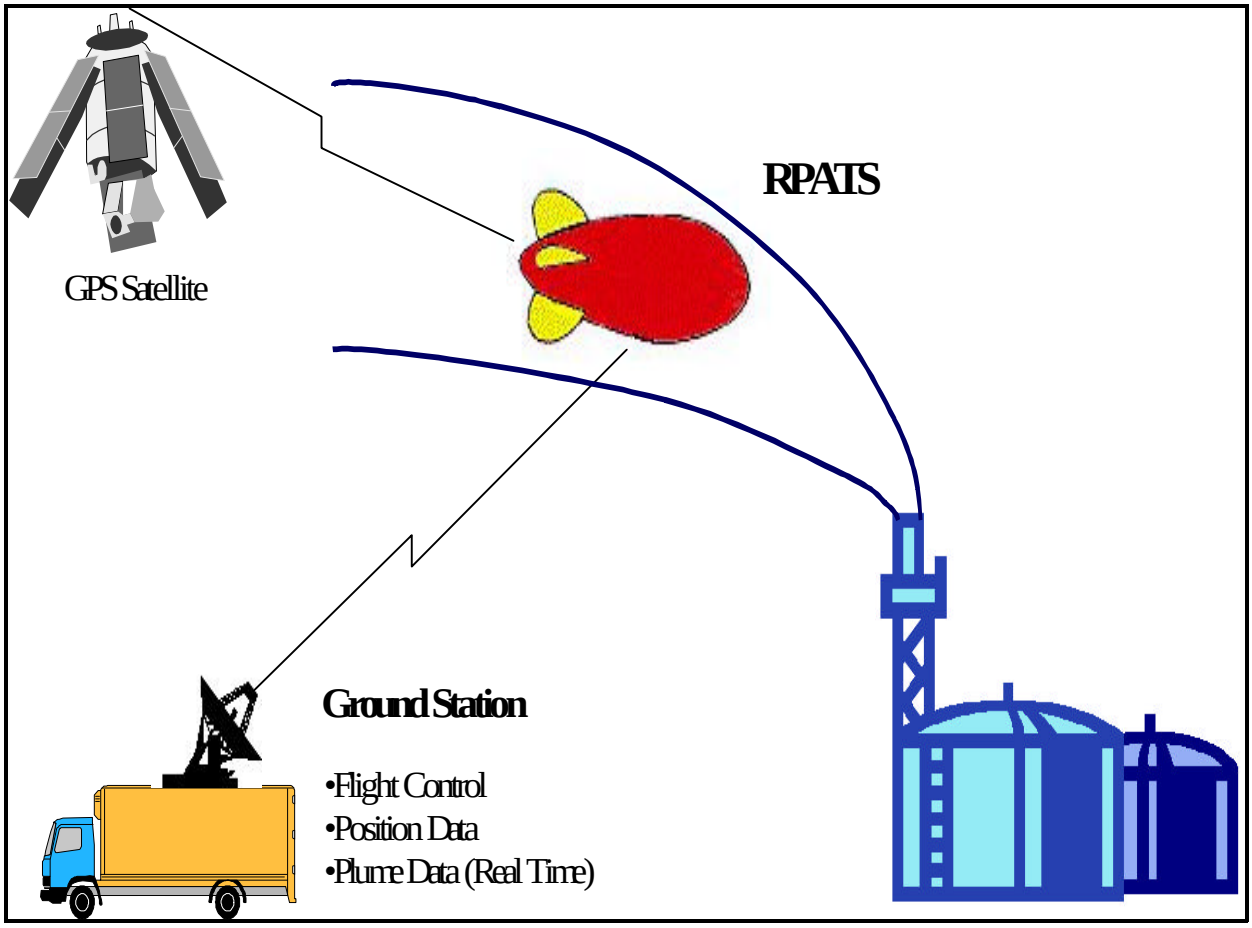

Figure 1. Concept Diagram of the RPATS Air Sampling Platform

The Clean Airship 1 consists of two main components: the remotely piloted airborne sampling platform and the ground-based control and data logging system. The airship continuously determines its position by means of a GPS receiver and transmits position, flight parameters, and concentration data to the ground station where the pilot uses the information to control the flight path of the airship. Under the initial research effort, Clean Airship 1 was equipped with a realtime SF_6 analyzer and the system was used to locate an SF_6-labeled plume[1,2] from a nearby emissions source. Once isloated, the Clean Airship1 pilot would direct the apparatus to fly cross-wind through the subject plume at various altitudes and distances downwind. Simultaneous to the concentration measurements, the airship also recorded ambient temperature. These three-dimensional data can then be used to

determine the dispersion and transport characteristics of the plume as well as the exact height of the plume[3-8]. Also contained in the database is information concerning plume interaction with stratified thermal layers of the lower atmosphere and to what extend plumes penetrate stable layers aloft.

1.2 Participation in the CRPAQS

The California Regional $PM_{10}/PM_{2.5}$ Air Quality Study (CRPAQS) objective is to ultimately improve scientific understanding of excessive suspended particulate matter (PM) levels in the central California region[9]. CRPAQS will help provide insight on how regulators will proceed to reduce PM exposure to populations in the San Joaquin Valley and other central California regions. As an integrated effort, the CRPAQS includes comprehensive air quality and meteorological measurements, emissions characterizations, data analysis, and air quality modeling. The CRPAQS activities are complementary to other long-term monitoring and research activities conducted by the U.S. Environmental Protection Agency (EPA), the California Air Resources Board (ARB) and numerous local air quality districts in the region.

The CRPAQS program goal is to "provide additional and more comprehensive information than is currently available to explain the nature and causes of particulate concentrations...in and around central California"[9]. This programmatic information will be used to adopt or modify control strategies for reducing PM in certain regions of central California. With this goal in mind, specific field study objectives were adopted. A portion of these objectives include:

- Characterize the source zones of influence and quantify source contributions to community exposure for PM chemical compounds, including particulates that are directly emitted and those that form from directly emitted gases.

- Quantify source contributions to secondary aerosols, identify limiting precursors, and assess the extent to which reductions in nitrogen oxides, ammonia, sulfur oxides, and volatile organic compounds would be effective in reducing PM concentrations.

- Refine conceptual models that explain the causes of elevated PM concentrations and interactions between emissions, meteorology, and ambient PM concentrations.

- Evaluate and improve the performance of emissions, meteorological, and air quality simulations. Apply simulation methods to estimate PM concentrations at receptor sites and to test potential emissions reduction strategies.

Clean Airship I provided an excellent opportunity to study the plume characteristics of fossil energy sources, particularly when operated under the adverse winter-time conditions experienced in the San Joaquin Valley. Upon the completion of proving the feasibility and workability of the prototype airship, the DOE and its research participants jointly funded a field sampling effort in support of CRPAQS. Under this initiative Clean Airship1 was used to study near term plume behavior and

conduct detailed mapping air quality plume structures related to specific fossil energy sources. These tests were conducted in the San Joaquin Valley during 15 episode days which occurred between December 1, 2000 and February 3, 2001 as part of the CRPAQS winter episodic field studies.

Scientists associated with the CRPAQS believe that secondary ammonium nitrate is generated by both surface sources and sources which release elevated plumes of oxides of nitrogen, following oxidation and reaction with ambient ammonia during stagnant wintertime fog episodes. Data from the Clean Airship I will define the extent of near-term plume characteristics exhibited by fossil energy plumes. This information could have significant influence on accurately projecting the impacts these sources have on downwind regions.

In support of the field studies, AERA Energy LLC, volunteered the use of its South Belridge oilfield as the test bed for Clean Airship 1 during the CRPAQS program. Consequently, an active gas fired steam generator plume was tagged with SF_6 tracer gas which served as the source of plumes to be studied. The AERA South Belridge oilfield served as an ideal location to operate the airship in that a decommissioned airfield on the lease was situated very near the candidate source (steam generator) and the area is isolated from the public. Due to the close proximity of this flight operations base relative to the subject plume, sampling sorties could be optimized by eliminating logistical and risk factors related more distant plumes in areas that have general public access.

Figure 2 below illustrates the Clean Airship 1 while performing one of its plume transects during CRPAQS.

1.3 Overview of the Database Generated

Approximately 28 sorties of flight data by Clean Airship 1 was collected during the CRPAQS winter episodic field studies. Each sortie last from 10 minutes to 50 minutes in duration. Plume sampling was conducted under a variety of conditions that were present during ARB forecasted Intensive Operation Periods (IOPs). Plume sampling and mapping were conducted only under light wind conditions (less that 7 mph) at distances from the source ranging from a few ten's of meters to downwind distances as far as several kilometers. Vertical data range from less than 50 meters to nearly 700 meters in altitude depending upon the vertical extent of the measured plumes. The limit of vertical sampling was approximately 700 meters due to the capabilities of the Clean Airship 1 (due to the near micro-scale of the measurements conducted, no plumes were seen at this altitude). Table 1 below provides a summary of the data collected by Clean Airship 1 in support of the CRPAQS. The initial analysis of this database toward addressing Task 6.4 of the RFP and their technical implications is the topic of this proposal.

Figure 2 - Clean Airship 1 Sampling Near Source Plume Structure

Table 1 - Summary of Data Collected

Date	Number of Flights	General Conditions
12/16/2000	3	Clear, Light Winds
12/17/2000	4	Cool, Low Ceiling
12/18/2000	1	Low Thin Fog, Cool
1/4/2001	6	Clear Light Winds
1/5/2001	4	Clear Light Winds
1/6/2001	4	Clear, Very Dry
1/7/2001	1	Clear, Light Winds
1/31/2001	2	Clear, Warm, Some High Winds
2/1/2001	3	Very Clear, Light Winds

2.0 Objectives of the Data Analysis Tasks

This section outlines the proposed steps (subtasks) encompassing the analysis of the Clean Airship 1 - CRPAQS database. The basis of the research effort is to ultimately understand the fate secondary particulates from gas fired fossil energy sources in the San Joaquin Valley (SJV) region. While Clean Airship 1 did not directly measure for secondary particulate plume concentration, it did collect very precise data on initial (near term) gaseous precursor (NOx plumes) dispersion, buoyancy, and transport (vertical and horizontal) which is important information regarding the modeling/assessment of particulate formation.

Data from Clean Airship 1, as it applies to the CRPAQS, will help regulators better understand the mechanisms by which plumes (or portions of such plumes) from elevated sources are entrained into the mixed layer, and the timing of entrainment. Clearly, use of an inert tracer does not allow one to follow the conversion of NOx to nitric acid, and the reaction of nitric acid with ammonia. However, the information gained from the tracer measurements provides a more realistic representation of how local NOx plumes interact with the ambient environment which allows for a better assessment of potential ground level concentrations of ammonium nitrate. In particular, the Clean Airship 1 database will afford a more confident understanding of whether and to what extent oilfield combustion sources, which emit NOx above the surface via elevated plumes, contribute to ground level ammonium nitrate concentrations. This information should contribute to effective and meaningful control strategies to reduce secondary particulate impacts.

Toward this end, Tracer ES&T proposes a two phased program. The initial effort will organize the airship database in a format that conforms to all data that is contained in the CRPAQS database. This will enable ARB scientists to independently evaluate and apply this data in their overall particulate control strategies for the SJV. Currently the data resides in its rawest form which entails concurrent data points comprised of information on concentration, time, airship position, meteorological conditions, source strength (flow, temperature, and dynamic concentration), source position parameters, calibration data, and supportive QA/QC information.

The next phase will be to accomplish tasks that provide some detailed analysis from which ARB may gauge for itself the implications of the measurement effort as well as provide definitive answers to the general RFP questions. Hence the following technical goals have been identified for this proposed effort:

- Organize Airship Database to Conform with CRPAQS Protocol
- Compare Plume Measurements with Existing Model Simulations
- Compare Actual Plume Rise Data with Existing Formulations
- Compare Plume Sigma Z and Sigma Y Values with Established Models
- Assess Plume Penetration/Breakthrough of Surface and Lifted Inversions
- Map Flight Data Information

- Document and Determine the Relative Accuracy of the Airship Database

Additionally, the proposed effort, will support the publication of a peer reviewed technical paper to be presented at a nationally recognized environmental conference such as the Air and Waste Management Association's annual meeting or similar forum for technical studies.

It is important to note that the authors of this program have already published/presented a technical paper of the field sampling portion of this research effort. It is entitled "Mapping Air Quality Plumes from Fossil Energy Sources to Assess the Impacts of Secondary Aerosol Development", Society of Petroleum Engineers, Publication No. 66502, February 2001.[10]

3.0 Technical Approach and Program Sub-Task Descriptions

Tracer ES&T has identified several technical sub-tasks (tasks) necessary to meet the objectives of the overall proposed effort. This section will provide a brief description of each task as it pertains to the initial analysis of the Clean Airship 1 - CRPAQS database in terms of addressing Task 6.4 of the October 22, 2001 ARB Request for Proposal entitled "California Regional PM10/PM2.5 Air Quality Study (CRPAQS) Initial Data Analysis of the CRPAQS Field Program Measurements".

3.1 Development of a Program Work-Plan

While this proposal provides a distinct set of recommended tasks, it is recognized that ARB should be afforded to opportunity to suggest alternative analysis approaches in order to tailor the program to specific ARB needs. Therefore, the first task to be conducted will include the development of revised tasks per unforseen needs of the ARB. This will be accomplished by way of an initial program kick-off meeting in Sacramento where the Tracer ES&T program manager, along with personnel from the Western States Petroleum Association and DOE will meet with appropriate ARB personnel to finalized the program task structure. During this meeting all aspects of the proposed data analysis effort (regarding to the Clean Airship 1) will be reviewed and altered as necessary to optimize the usefulness of the data. ARB will have final say on the analysis tasks required in the final work plan and Tracer ES&T will prepare a Final Work Plan document before initiating any task assignments.

3.2 Categorize and Re-organize the Database to meet ARB Protocol

As an initial step in the research, it is proposed that the existing databases be modified such that they conform to the general data format used by the ARB for the CRPAQS databases. Once the exact protocol and format has been conveyed to Tracer ES&T, a copy of the data files can be provided to the ARB for safe keeping. Tracer ES&T will retain a working copy in order to conduct research/analysis efforts in subsequent tasks. This way, the airship data becomes part of the public record for other groups to possibly consider in their analysis efforts.

3.3 Supplement Airship Database with Local Meteorological Data from CRPAQS

Concurrent to all CRPAQS winter episodic field studies, Tracer ES&T monitored and recorded basic meteorological data in support of the Clean Airship 1 operations. Included in these measurements where 5 min. averages of wind speed, wind direction, and ambient temperature at the South Belridge Oilfield. It may be beneficial to the analysis of the Clean Airship 1 database to incorporate any additional detailed meteorological information which was collected by the CRPAQS network during IOPs. This is especially true regarding any local or regional assessments of atmospheric stability and vertical temperature structure of the atmosphere. In this task, Tracer ES&T scientists will survey the existing CRPAQS databases to consider applicability to the analysis tasks contained in the Final Work

Plan. Appropriate steps will be taken to obtain access to supplemental data sets as they are needed.

3.4 Determine Measured Sigma Y and Sigma Z Values

During IOPs, Clean Airship 1 was maneuvered to obtain numerous transect readings of subject plumes. In a given sortie, 15-20 crossectional measurements were made of downwind plumes. This data should be plotted and analyzed to determine measured Gaussian model "Sigma Y and Sigma Z" values. This should be performed for each transect as well for "combined" transects comprised of several single transects collected a over contiguous time period. Tracer ES&T is hopeful that the data will produce measured sigma values for a variety of time periods ranging from instantaneous plumes to plume structure on the hourly time scale. The definition of sigma parameters will take on the that describe by Turner[11] in his Workbook on Atmospheric Estimates. In all cases, as the averaging period increases, plume meander versus changes in mean wind direction will be accounted for in the determination of sigma values. Figure 3 provides an illustration of several Gaussian fits of plume transect data.

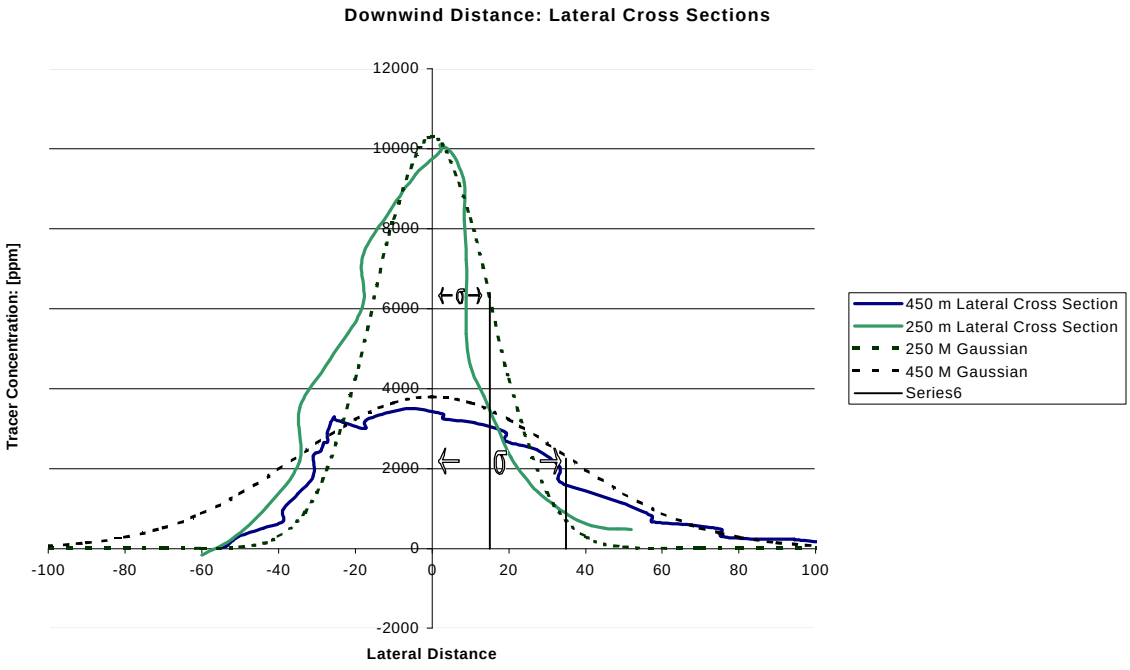

Figure 3 - Gaussian Fit of Plume Transects

3.5 Determine Plume-Rise from the Clean Airship I Data

Clean Airship 1 collected comprehensive plume mapping data to determine not only the maximum vertical extent of the subject plumes but to determine centerline positions and lower boundaries of the subject plumes. Relative to each sortie, Tracer ES&T will determine the plume centerline height above the ground surface as a function of near term downwind distance.

3.6 Compare Measured Sigma Values to Published Values

Once the raw databases have been analyzed to determine various representations of dispersion parameters (sigma values as a function of downwind distance, stability, and time averaging period) the results will be compared to generally published dispersion parameter values such as those found in Turner or those used in the EPA dispersion models such as the ISCST model. Any significant differences and trends will be noted with regard to the overall program objectives. While there may not be enough data to statistically support a modification of such parameter values in existing models, ample data exists to suggest trends or note departures from the generally published models.

3.7 Compare Empirical Plume-Rise to Modeled Estimates

Data summaries and analysis results from sub-task 5 will be compared to standard formulations of plume rise commonly used in EPA models. In this task, several plume rise formulation will be exercised with source and local meteorological data collected during the testing program. Modeled projections will be compared with actual measurements of plume-rise from the Clean Airship 1 database. As in sub-task 6 above, while there may not be enough data to statistically support a modification in plume rise formulations, enough data exists to reveal consistencies and departures from the generally published assessments/models. The proposed formulations for plume rise which will be used in this analysis will include:

- The Davidson-Bryant Formula (empirical)[12]
- The Holland Formula (empirical)[12]
- The Bosanquet Formula (semi-empirical)[12]
- Dimensional-Analysis Formulas as Modified by Briggs (semi-empirical)[12]

Formulations for plume rise that are used in current EPA models and differ from the above will also be considered in the analysis. The final work plan will identify the actual plume rise formulations which will be studied and/or confirmed.

3.8 Determine the Rate of Vertical Plume Mass Infiltration into Lifted Stable Layers

One of the most significant and important aspects the Clean Airship 1 database is that it documented plume excursions into lifted stable layers of the local atmosphere. The fact that near term plumes can penetrate low level inversions may have significant implications on how long range transport of emissions occur in the SJV. The database from Clean Airship 1 may reveal not only the phenomena that this vertical transport exists, but provides a means of quantifying just how much plume mass actually is entrained aloft. Figure 4 provides just a "snapshot" example from the Clean Airship 1 database regarding this phenomena. From this data presentation, it is noted that a significant portion of the plume mass was found within the lifted stable layer. It is important to note that this plume data was comprised from a number of plume transects compiled during a single sortie. (Please note that the temperature scale along the "x" axis is not plotted).

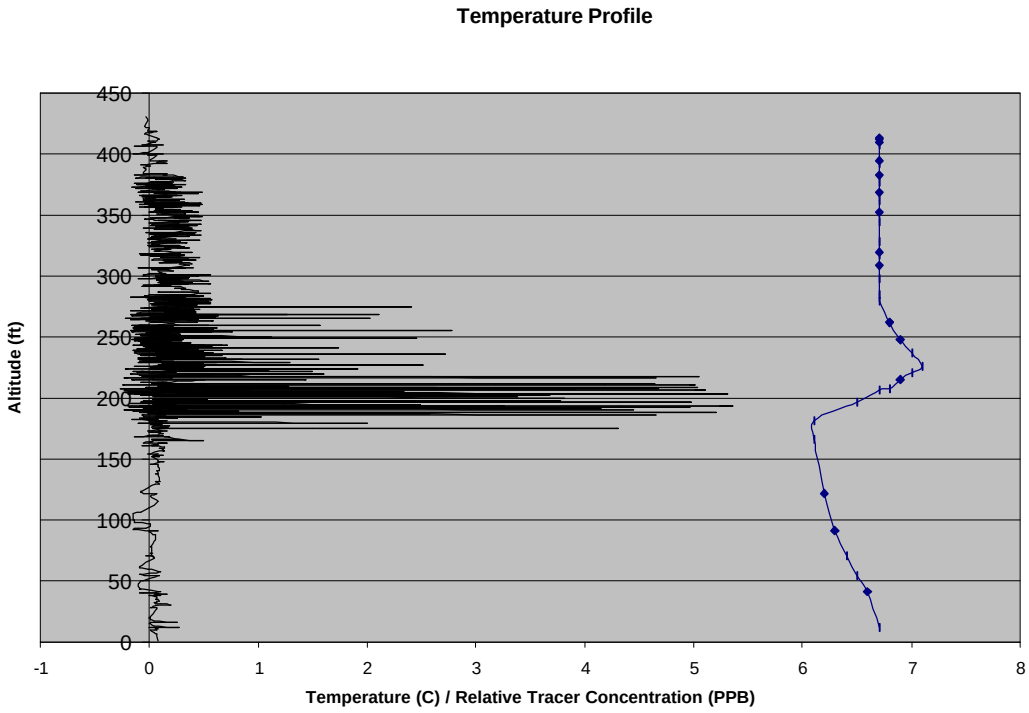

Figure 4 - Plume Entrainment into a Stable Layer

3.9 Clean Airship I Database Error Analysis

A complete error analysis will be conducted on the entire database. Error and accuracy will be determined from calibration and QA/QC documentation such that each data point will be assigned an error bar and/or a measure of relative accuracy. Data precision will be defined by similar methods by which most air pollutant measurements are defined. These methods are detailed in EPA publications entitled "Quality Assurance Handbook for Air Pollution Measurement Systems", March 1976 (EPA-600/9-76-005 and EPA-450/4-80-12) and are commonly used in most nationally recognized ambient measurement programs.

The systems for which error will be assigned include:

- Tracer ES&T Realtime Monitor for SF6
- Themistor on the Airship
- Surface Wind (WS/WD) Sensors
- Tracer (SF6) Release System
- Stack Probes and Flow Measurement Systems
- Airship GPS
- Airship Altimeter

All of the above data error will be interrelated and integrated to determine the precision of the actual plume measurements. Error values or confidence indices will be assigned to each data point as part of the error analysis.

3.10 Conclusions, Reporting, and Publications

The technical findings of this data analysis effort will be conveyed by way of a formal technical program report, progress reports, and individual task summary reports. During each month of operation, the Tracer ES&T program manager will submit a Progress Report which will highlight the previous month's technical accomplishments, outline budget expenditures, and detail the work to be accomplished in the next period. At the conclusion of each task, Tracer ES&T will provide ARB a brief summary report of the work completed and the basic findings from the complete task effort. Upon completion of all technical tasks, Tracer ES&T will prepare a Draft Data Analysis Report on Vertical Plume Measurements Conducted During CRPAQS Winter Program Utilizing Clean Airship 1. Upon review by ARB on this draft report, Tracer ES&T will prepare a Final version. All reports will be submitted according to RFP requirements which include hard-copies (10 plus original), PDF read only electronic files, and an MS Word "doc" file.

Upon complete of the final report or before, Tracer ES&T, Inc. will prepare a technical article to be peer reviewed and published and presented at a national conference (such as Air & Waste

Management Association or other similar organization). Upon request of the ARB, Tracer ES&T will provide co-authorship to ARB program coordinators and/or other personal as deemed appropriate. Tracer ES&T will also present program findings at a selected national conference. In the event a paper is present for publications, ARB and Tracer ES&T authors will agree to assign copyright privileges to the publisher, if requested.

A technical paper on the methods employed to collected data that is the subject of this proposal has already been authored and presented. Reference 11 in Section 7.0 describes this publication.

3.11 Communications, Meetings, and Presentations

Three program meetings in Sacramento are planned for this project. This will include a initial kick-off meeting where the basis for a Work Plan will be discussed and any changes to the project task structure will be discussed and agreed upon. A second program meeting will be arranged upon the completion of Tasks 1-5. At this meeting, the initial analysis of the program data will be presented and an assessment of the data implications will be discussed. At this time, should the ARB Program Manager decide to alter any of the remaining tasks based upon the outcome of the project material presented, plans to do so could be initiated at this meeting. A final meeting is planned to discuss ARB's review and comments on the draft conclusions report. Based upon the comments received and the recommendations of ARB staff, Tracer ES&T will prepare the final report.

As with all projects, Tracer ES&T relies heavily on e-mail communications. Additionally, project submittals and reports drafts could be accomplished by e-mail and use of the Tracer ES&T web page. This will help to reduce program costs and limit the unnecessary use of paper.